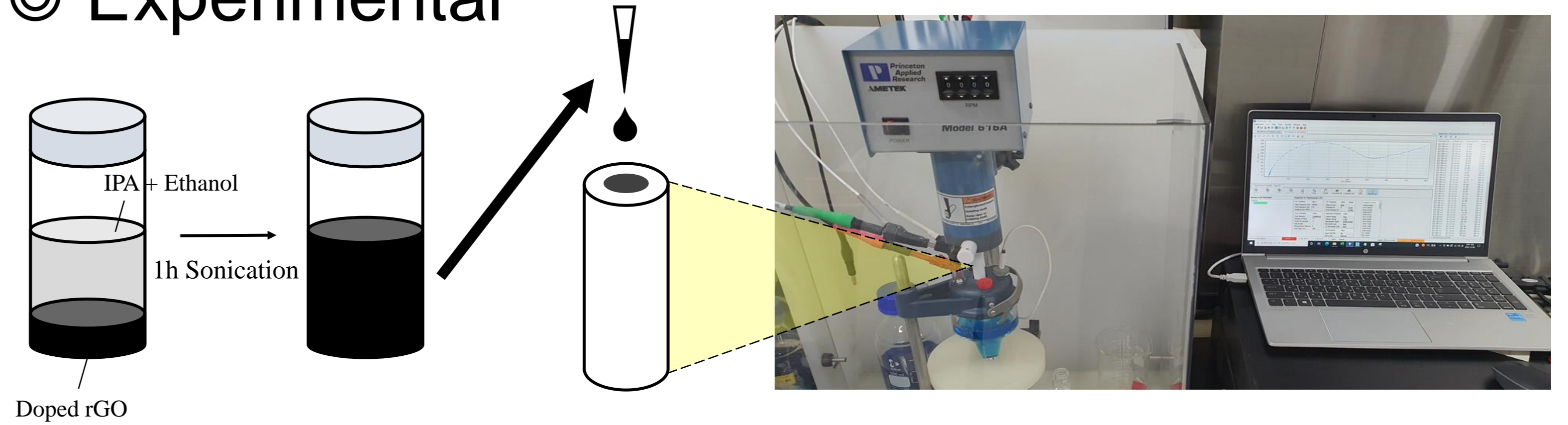


◎ Introduction

- The **redox flow battery (RFB)** is emerging as a potential grid-scale electric energy storage system (ESS) to cope with the intermittent nature of solar and wind power.
- **vanadium redox flow battery (VRFB)**, which utilizes vanadium ion pairs for both the positive- and the negative-side redox reactions is currently one of the leading RFB systems, and in an early stage of commercial deployment.
- The purpose of this study is investigating and analyzing **kinetic effects of hetero atom doped graphene** for vanadium redox kinetics by using electrochemical impedance spectroscopy(EIS)

◎ Experimental



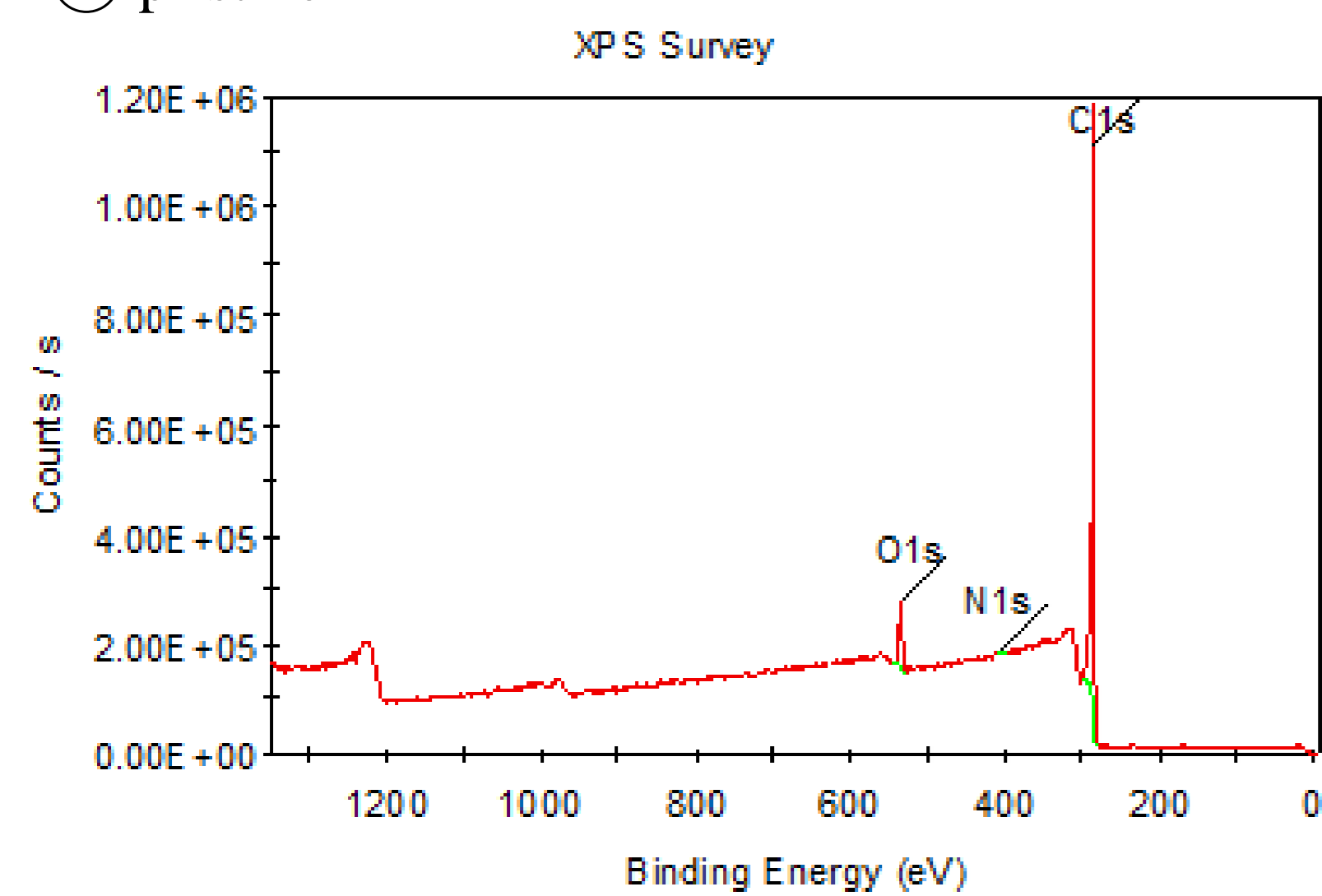
Each carbon materials disperse in specific solution (rGO 0.04g + Ethanol 4 mL+ iso-propanol 1 mL)

- 1) Using dispersion solution, we put 6 μ L 2~3 times carbon materials on surface of glassy carbon(GC) electrode with micro pipette.
- 2) Electrocatalytic properties of carbon materials were characterized by EIS.

◎ Results and Discussion

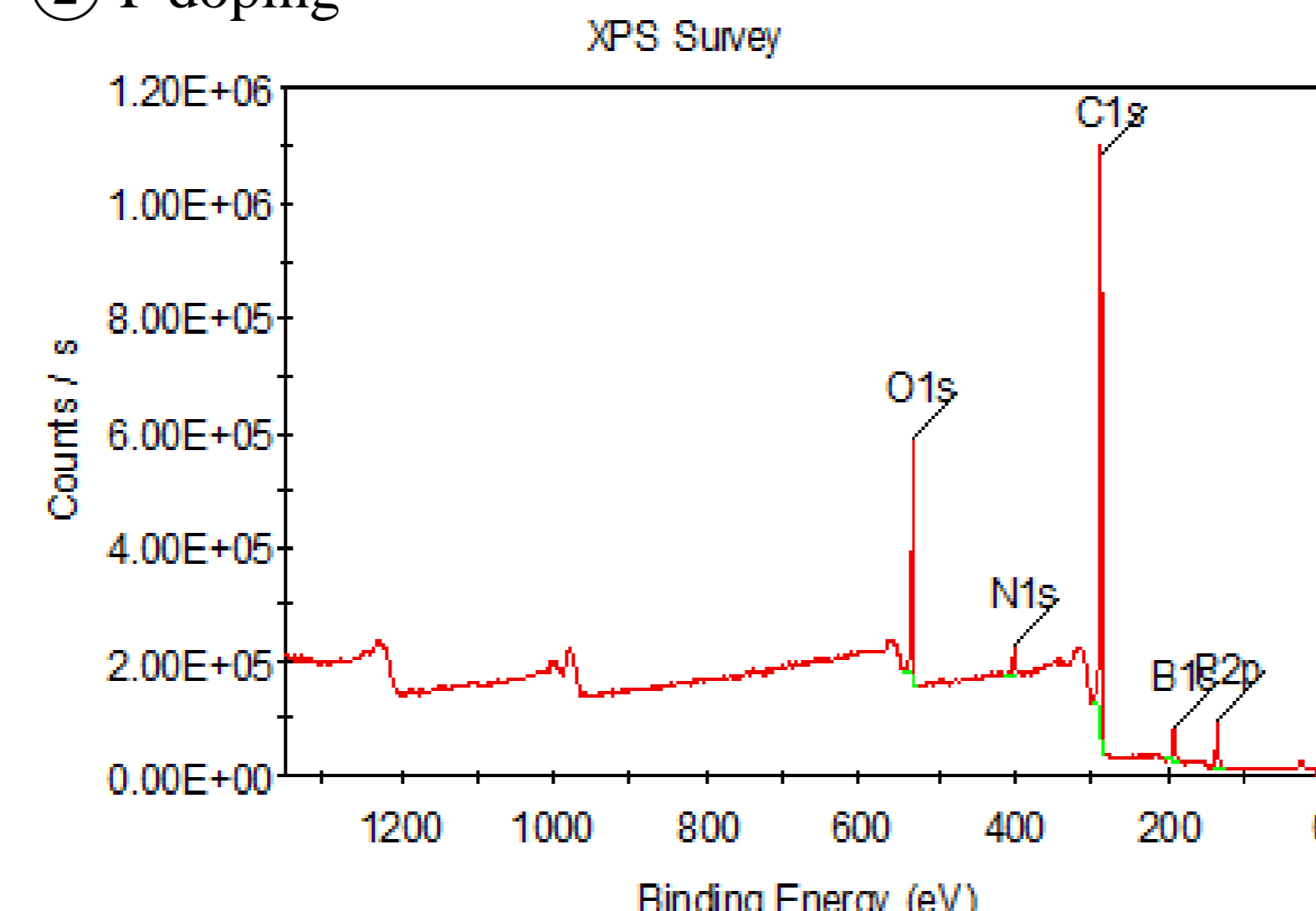
- XPS results of each doped graphene

① pristine



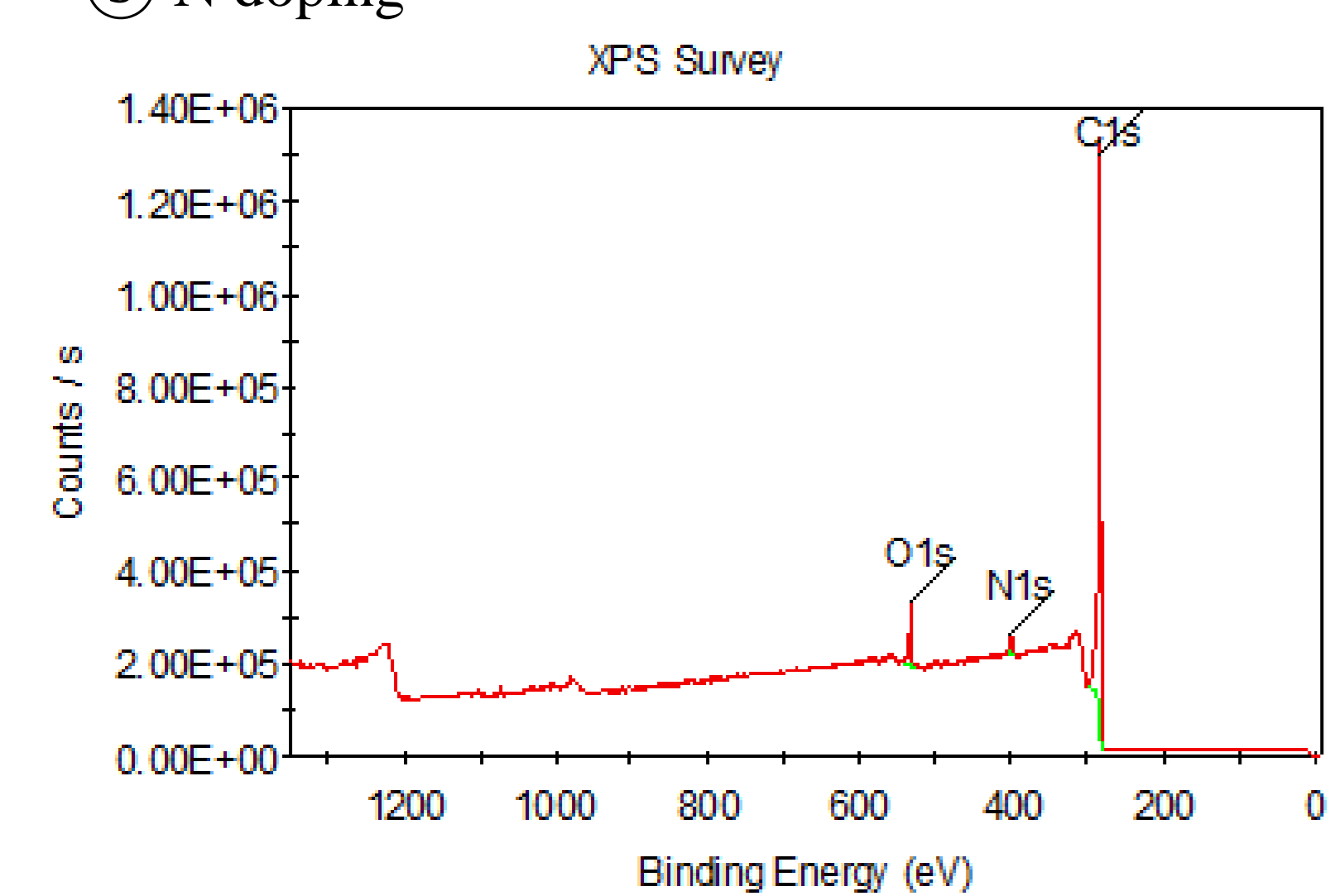
Name	C1s	N1s	O1s
Atomic%	92.51	0.28	7.2

② P doping



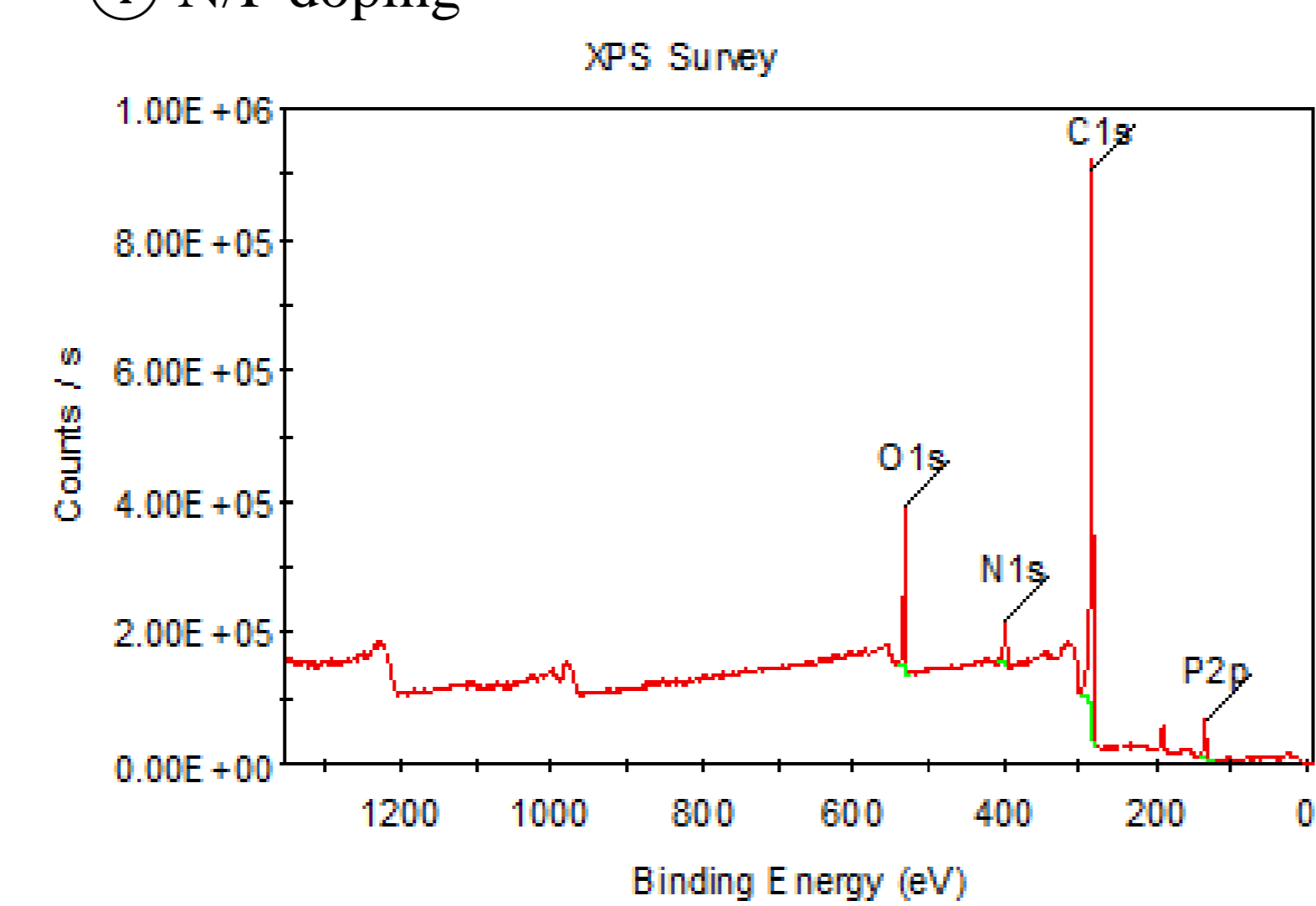
Name	C1s	N1s	O1s	P2p
Atomic%	92.51	0.28	7.2	3.95

③ N doping



Name	C1s	N1s	O1s	B1s
Atomic%	89.29	3.34	5.72	1.65

④ N/P doping

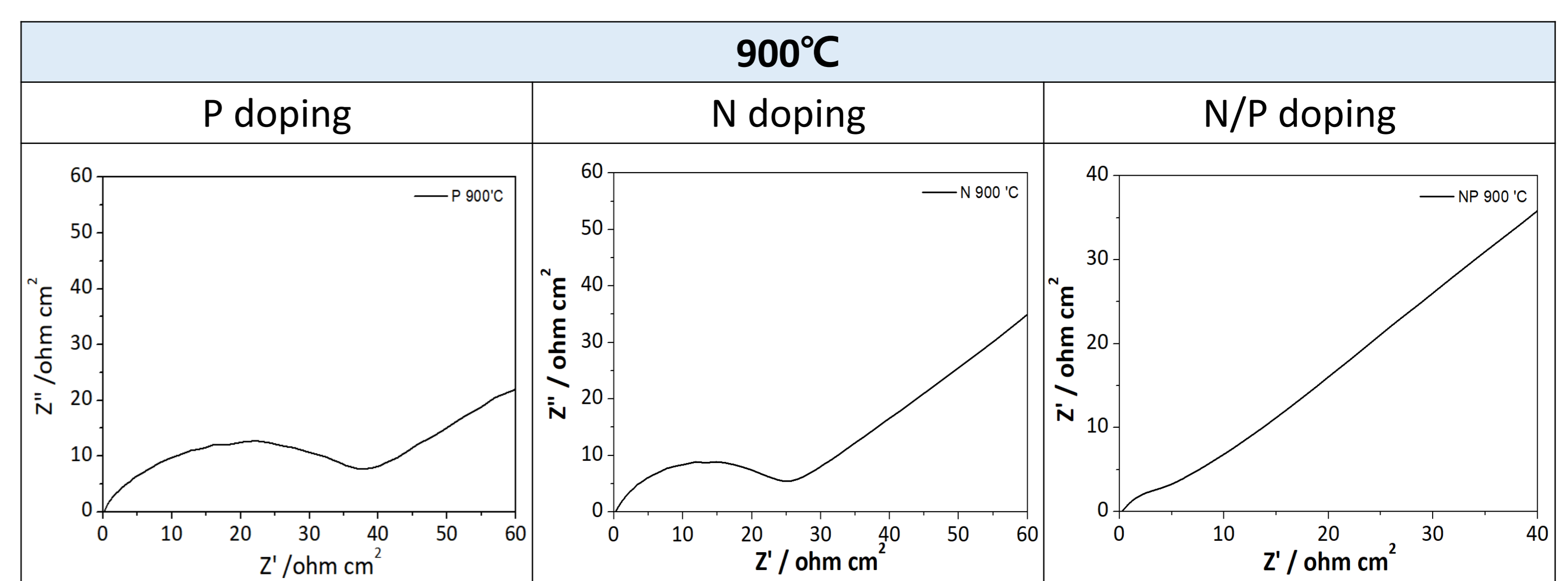
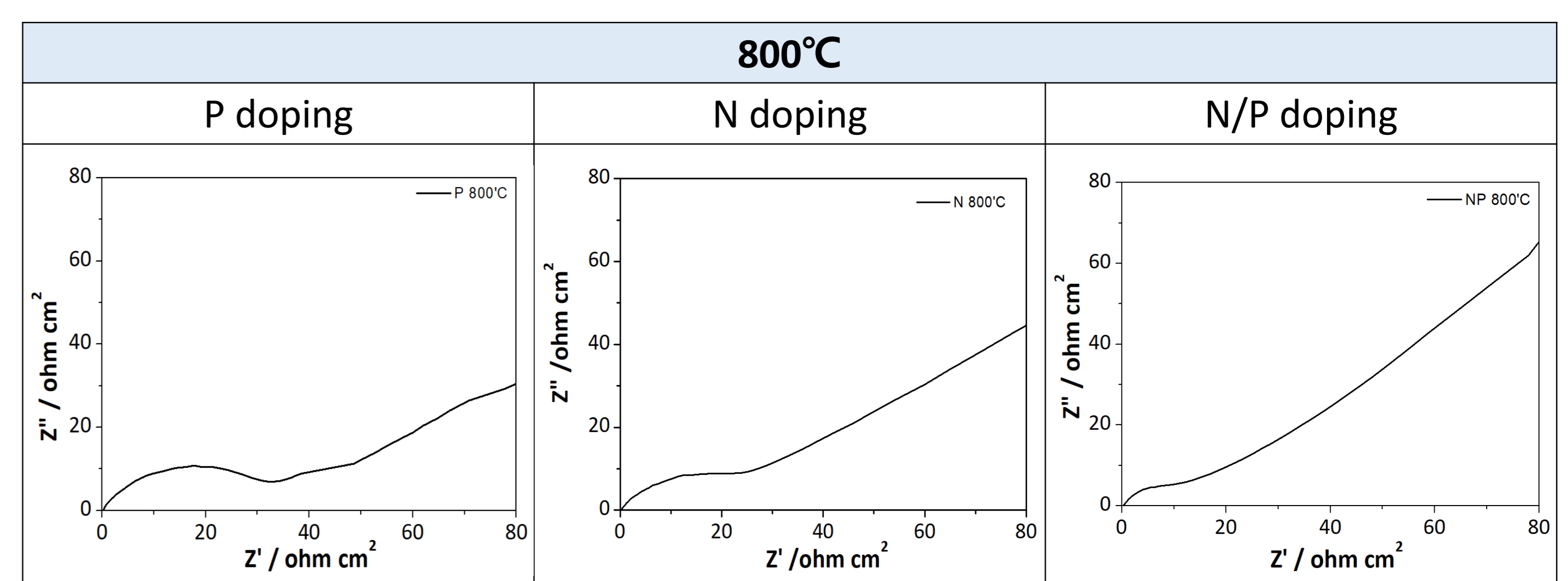
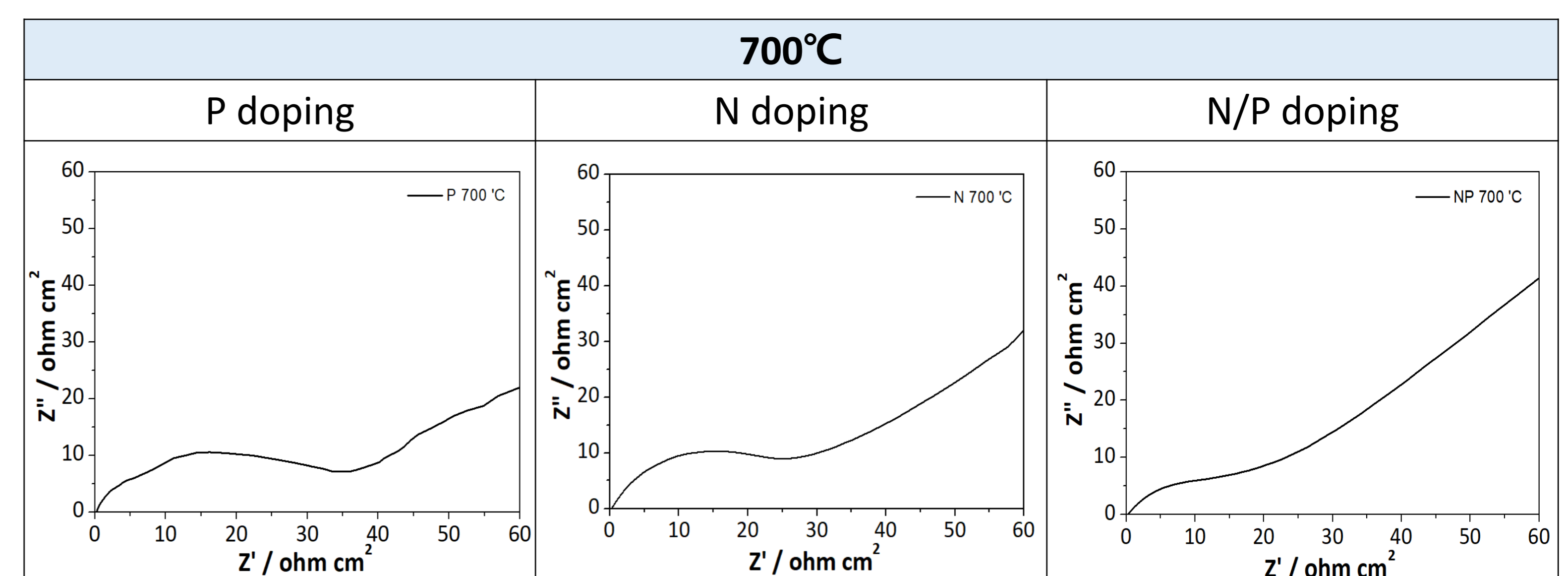
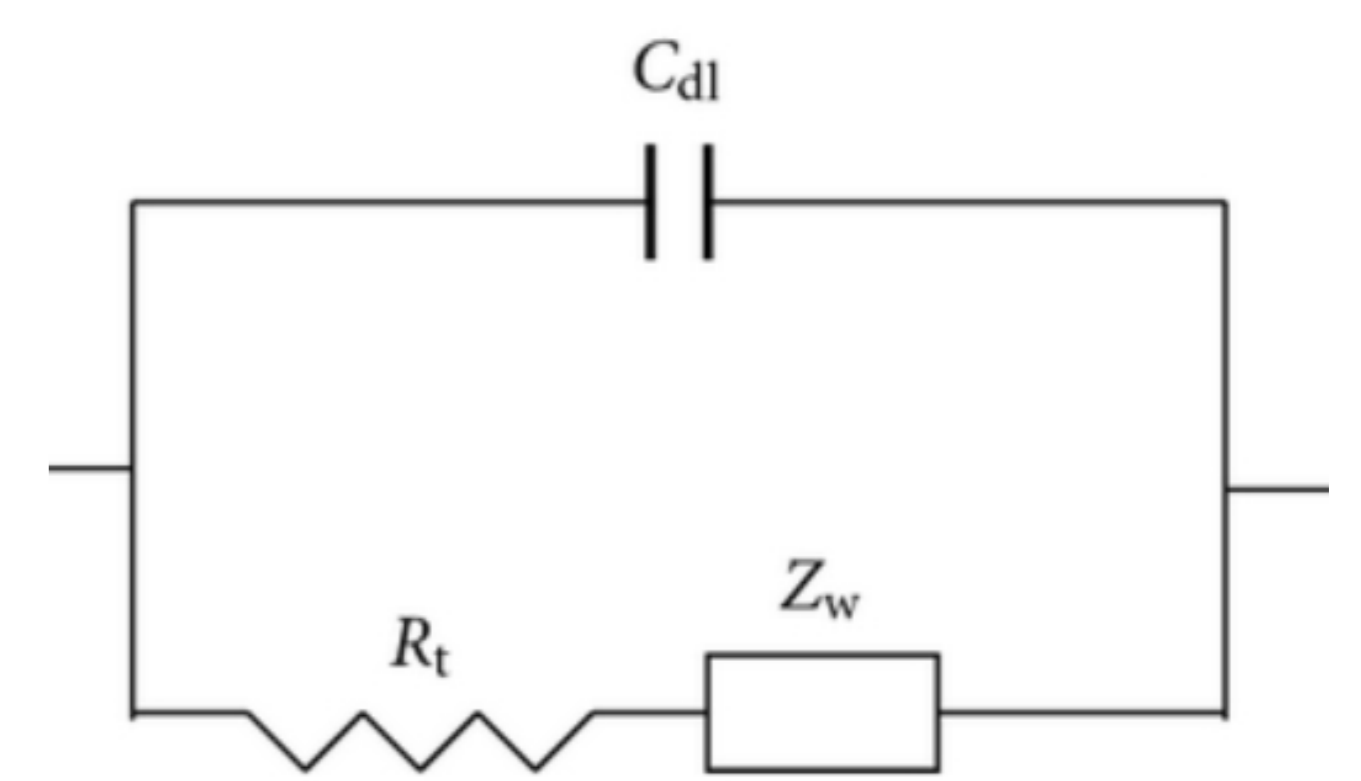
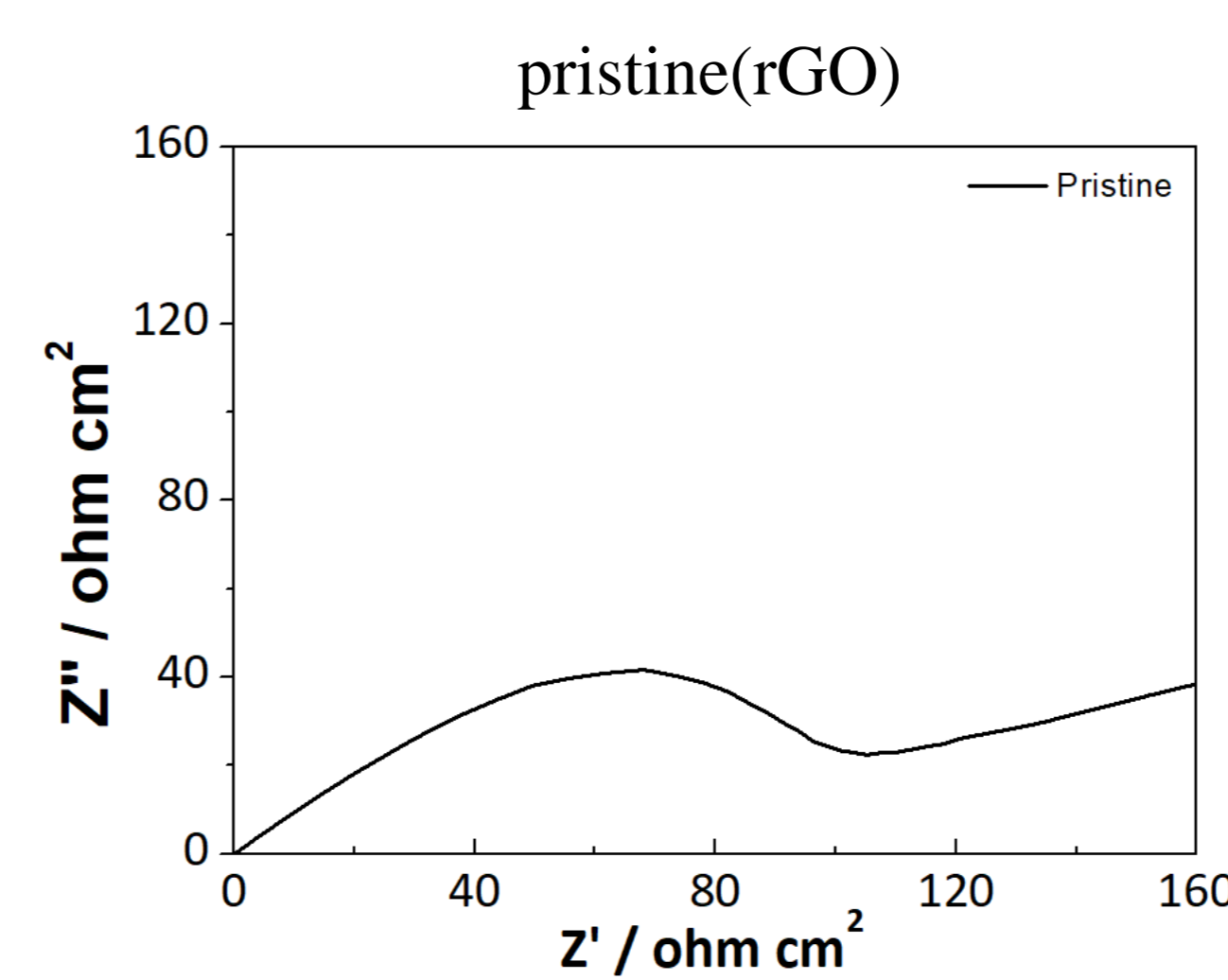


Name	C1s	N1s	O1s	B1s	P2p
Atomic%	66.69	5.03	11.1	13.43	3.75

⑤ XPS data

Pristine		P doping		N doping		P, N doping	
Name	Atomic%	Name	Atomic %	Name	Atomic %	Name	Atomic %
C1s	92.51	P2p	3.95	B1s	1.65	P2p	3.75
N1s	0.28	B1s	14.31	C1s	89.29	B1s	13.43
O1s	7.2	C1s	63.73	N1s	3.34	C1s	66.69
-	-	N1s	3.00	O1s	5.72	N1s	5.03
-	-	O1s	15.02	-	-	O1s	11.1

- EIS results of each doped graphene
- rGO open circuit model of carbon materials.



◎ Conclusions

- 1) Effects of Hetero atom doped graphene are analyzed by using XPS and various electrochemical analysis method, EIS.
- 2) Hetero atom doped graphene makes vanadium redox reaction rate high and charge transfer resistance low.
- 3) Each atomic doping has a different functionality and they must be used properly depending on the situation.